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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

INVESTIGATION OF SPINNING AND TUMBLING CHARACTERISTICS OF A 1/20-SCALE MODEL OF THE CONSOLIDATED VULTEE XFY-1 AIRPLANE IN THE FREE-SPINNING TUNNEL

TED NO. NACA DE 370

By Henry A. Lee

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel on a 1/20-scale model of the Consolidated Vultee XFY-1 airplane with a windmilling propeller simulated to determine the effects of control setting and movements upon the erect spin and recovery characteristics for a range of airplane-loading conditions. The effects on the model's spin-recovery characteristics of removing the lower vertical tail, removing the gun pods, and fixing the rudders at neutral were also investigated briefly. The investigation included determination of the size parachute required for emergency recovery from demonstration spins. The tumbling tendencies of the model were also investigated. Brief static force tests were made to determine the aerodynamic characteristics in pitch at high angles of attack.

The investigation indicated that the spin and recovery characteristics of the airplane with propeller windmilling will be satisfactory for all loading conditions if recovery is attempted by full rudder reversal accompanied by simultaneous movement of the stick laterally to full with the spin (stick right in a right spin) and longitudinally to neutral. Inverted spins should be satisfactorily terminated by fully reversing the rudder followed immediately by moving the stick laterally towards the forward rudder pedal and longitudinally to neutral. Removal of the gun pods or fixing the rudders at neutral will not adversely affect the airplane's spin-recovery characteristics, but removal of the lower vertical tail will result in unsatisfactory spin-recovery characteristics. The model-test results showed that a 13.3-foot wing-tip conventional parachute (drag coefficient approximately 0.7) should be effective as an emergency spin-recovery device during demonstration spins of the airplane. It was indicated that the airplane should not tumble and that no unusual longitudinal-trim characteristics should be obtained for the center-of-gravity positions investigated.

INTRODUCTION

In accordance with a request of the Bureau of Aeronautics, Department of the Navy, an investigation was performed in the Langley 20-foot free-spinning tunnel to determine the spin, spin-recovery, tumbling, and longitudinal-trim characteristics of a 1/20-scale dynamic model of the Consolidated Vultee XFY-1 airplane. The XFY-1 is a vertically rising airplane having a modified delta-wing plan form with a 55° sweptback leading edge and no horizontal tail. The vertical tail which extends both above and below the fuselage also has a modified delta shape with a 40° sweptback leading edge. The XFY-1 has a large-diameter dual-rotation propeller.

The erect-spin and recovery characteristics and the tumbling characteristics were determined for the full gross-weight loading and for an alternate loading condition with the model in the clean condition without the propeller installed. Tests were also made to determine the effects of the windmilling propeller on the spinning and tumbling characteristics of the model by adding fin area to the model nose. Brief spin tests were conducted to determine the effects of removing the lower vertical tail, removing the wing-tip gun pods, and fixing the rudders at neutral. The size wing-tip and tail parachutes required for emergency recovery from the spin was also investigated. Brief static force tests were performed to determine the aerodynamic characteristics of the model in pitch at attitudes above the stall.

SYMBOLS

b	wing span, ft
S	wing area, sq ft
c	wing or elevator chord at any station along span
$\bar{c}$	mean aerodynamic chord, ft
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage center line to mean aerodynamic chord (positive when center of gravity is below fuselage center line)

m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-ft^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slugs/cu ft
μ	relative density of airplane, $m/\rho Sb$
α	angle between fuselage center line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg
ϕ	angle between span axis and horizontal, deg
V	full-scale true rate of descent, fps
Ω	full-scale angular velocity about spin axis, rps
σ	helix angle, angle between flight path and vertical, deg; for tests of model, average absolute value of helix angle was approximately 1.5°
β	approximate angle of sideslip at center of gravity, deg; sideslip is inward when inner wing is down by an amount greater than helix angle
D	drag, lb
L	lift, lb
M	pitching moment about center of gravity, ft-lb
q	dynamic pressure, lb/sq ft
C_D	drag coefficient (D/qS)

C_L lift coefficient (L/qS)

C_m pitching-moment coefficient $(M/qS\bar{c})$

APPARATUS AND METHODS

Model

The 1/20-scale model of the Consolidated Vultee XFY-1 airplane was furnished by the Bureau of Aeronautics, Department of the Navy, and was prepared for testing by the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics. A three-view drawing of the model as tested is shown in figure 1. A photograph showing the model in the normal flying configuration without the propeller installed is shown as figure 2. Dimensional characteristics of the airplane as simulated by the model are presented in table I. After the model had been completed and prepared for testing it was learned that the fuselage had been lengthened somewhat and that the wing leading- and trailing-edge sweep angles had been altered slightly. These changes were not incorporated into the model because it was felt that they would have little effect on the results obtained.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 20,000 feet (ρ = 0.001267 slug/cu ft). A magnetic remote-control mechanism was installed in the model to actuate the controls for the recovery attempts and to open the parachute for the parachute tests. Sufficient moments were exerted on the controls for the recovery attempts to reverse them fully and rapidly.

Lateral and longitudinal controls were combined in one pair of control surfaces called elevons. Longitudinal control was obtained by deflection of the elevons in the same direction and lateral control was obtained by deflection of the elevons differentially. However, in this paper, elevon deflections for longitudinal and lateral control will be referred to, for simplicity, as elevator and ailerons deflections, respectively.

The windmilling propeller was simulated on the model by setting four fins in the propeller disk, two parallel to the plane of symmetry and two normal to the plane of symmetry. Fin area used to simulate the windmilling propeller was calculated according to the methods given in reference 1. A drawing showing the simulated propeller for 15° and 70° blade angles is shown in figure 3. Ordinarily propellers are not simulated on spin models because unpresented test results have shown that conventional windmilling propellers have little effect on model spin or spin-recovery characteristics. The propeller was simulated on this design, however, because the XFY-1 propeller is large and it appeared possible that the propeller might affect the spin and recovery characteristics of the model.

Wind-Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to that described in reference 2 for the Langley 15-foot free-spinning tunnel.

Spin tests.- The launching technique for the model spin tests has been changed from that described in reference 2 in that the model is now launched by hand, with rotation, into the vertically rising air stream. After a number of turns in the established spin, recovery is attempted by moving one or more controls. After recovery the model dives into a safety net. In those instances when the model does not recover it is lowered into the safety net. A photograph of the model during a spin is shown as figure 4.

The spin data presented were obtained and converted to corresponding full-scale values by methods described in reference 2. The turns for recovery were measured from the time the controls were moved, or the parachute was opened, to the time the spin rotation ceased and the model dived into the net. For recovery attempts in which the model struck the safety net while it was still in a spin, the recovery was recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, as >3. A >3-turn recovery does not necessarily indicate an improvement over a >7-turn recovery. For recovery attempts in which the model did not recover, the recovery result was recorded as ∞. When the model recovered without rudder movement, with the rudder with the spin, the results were recorded as "no spin".

Spin-tunnel tests are usually made to determine the spin and recovery characteristics of the model at the normal spinning control configuration (elevator full up, ailerons neutral, and rudder full with the spin) and at various other aileron-elevator control combinations including zero and maximum deflections. Recovery is generally attempted by rapid full rudder reversal. Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the ailerons are set at one-third of the full deflection in the direction conducive to slower recoveries and the elevator is set at two-thirds of its full-up deflection or full up, whichever is conducive to slower recovery. Recovery is attempted by rapidly reversing the rudder from full with the spin to two-thirds against the spin, by simultaneous rudder and elevator movement, or, for models within the mass range of the present model, by simultaneous rudder reversal to two-thirds against the spin and movement of ailerons to two-thirds with the spin. This control configuration and manipulation is referred to as the "criterion spin". Recovery characteristics of the model are considered satisfactory if recovery from this criterion spin requires $2\frac{1}{4}$ turns or less. This value has been selected on the basis of full-scale-airplane spin-recovery data that are available for comparison with corresponding model test results.

The full-scale rudder-pedal force necessary to move the rudder for recovery in a spin was determined from model tests. For these tests, tension in the rubber band which pulls the rudder against the spin was adjusted to represent a known value of the model rudder hinge moment about the rudder hinge line and recovery tests were run. The tension was reduced systematically until the turns for recovery began to increase. The model rudder hinge moment at this point was then converted to a full-scale rudder-pedal force at the equivalent altitude at which the tests were run.

For the spin-recovery parachute tests, the minimum-size wing-tip or tail parachute required to effect recovery within $2\frac{1}{4}$ turns was considered satisfactory. For these tests, the parachute was opened for the recovery attempts by actuating the remote-control mechanism and the rudder was held with the spin so that recovery was due entirely to parachute action alone. For the tail-parachute tests, the towline was attached to the model at the rear of the fuselage just above the jet exhaust and the parachute was packed either above the outboard wing or the inboard wing on the fuselage area between the base of the rudder and the inboard end of the elevon. Brief tests were also conducted with the towline attached to the tip of the vertical tail, the parachute being packed near the tip of the tail on the outboard side. For the model tests, locating the packed parachute in the locations indicated did not affect the established spin appreciably. Wing-tip parachutes were attached to the outer wing tip just in front of the elevon hinge line. The folded wing-tip parachute was placed on the wing in such a position that it did not seriously influence the established spin. For the model tests, a rubber band holding the packed parachute to the wing or fuselage was released and the parachute was opened merely by the action of the air stream. On the full-scale parachute installation it would be desirable to mount the parachute pack within the airplane structure, and it is considered desirable that a positive ejection mechanism be employed to eject the parachute.

Tumbling tests.- Two methods of launching were employed in determining the susceptibility of the model to tumbling. For one method, the model was held at an attitude approximately 180° to the vertical air stream and was then dropped, thus simulating a whip-stall condition.

For the second method of launching, the model was held at approximately 180° to the air stream and then given an initial pitching rotation by hand. The resulting motions were observed and photographed.

If a model tumbles with either method of launching, it is taken as an indication that the corresponding airplane can tumble although the airplane would be more likely to tumble if the model started tumbling when launched without pitching rotation. If the model stops tumbling after being launched with initial pitching rotation, the results are interpreted to mean that the corresponding airplane will not tumble.

Force tests.- The lift, drag, and pitching-moment data were obtained by mounting the model on a six-component strain-gage balance in the Langley 20-foot free-spinning tunnel. Tests were run with all controls neutral.

PRECISION

The model spin-test results presented are believed to be true values given by the model within the following limits:

α, deg	± 1
ϕ, deg	± 1
V, percent	± 5
Ω, percent	± 2

Turns for recovery:

From motion-picture records	$\pm 1/4$
From visual observation	$\pm 1/2$

The preceding limits may have been exceeded for some of the spins in which it was difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

Comparison between model and full-scale results in reference 3 indicated that model tests satisfactorily predicted full-scale recovery characteristics approximately 90 percent of the time and for the remaining 10 percent of the time the model results were of value in predicting some of the details of the full-scale spins. The airplanes generally spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 3 also indicated that generally the airplanes spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding models, the higher rate of descent of airplane on model, however, being generally associated with the smaller angle of attack. This comparison was made primarily for unswept wing designs, however, and may not be strictly applicable to the XFY-1.

Because it is impracticable to ballast the model exactly and because of inadvertent damage to the model during tests, the measured weight and mass distribution of the XFY-1 model varied from the true scaled-down values within the following limits:

Weight, percent	0 to 1 high
Center-of-gravity location, percent $\bar{c}$	0 to 1 rearward

Moments of inertia:

I_X, percent	7 low to 2 high
I_Y, percent	0 to 3 high
I_Z, percent	0 to 3 high

The accuracy of measuring weight and mass distribution is believed to be within the following limits:

Weight, percent	± 1
Center-of-gravity location, percent $\bar{c}$	± 1
Moments of inertia, percent	± 5

Controls were set with an accuracy of $\pm 1^\circ$.

TEST CONDITIONS

The mass characteristics and inertia parameters for loadings possible on the airplane and for the loadings tested on the model are shown in table II and plotted in figure 5. Unless otherwise indicated, all tests were conducted with gun pods installed on the wings.

The maximum control deflections (perpendicular to the hinge lines) used in the tests were as follows:

Rudder, deg	30 right, 30 left
Elevator, deg	30 up, 30 down
Ailerons, deg	20 up, 20 down

Initial tests were conducted with a maximum ailerons throw of only $\pm 10^\circ$ (measured perpendicular to the hinge line). After the test program had begun, the NACA was notified that the aileron deflections had been changed. The major portion of the tests were made with the revised aileron settings and results are presented only for the revised aileron deflections. The angular deflections of the elevons plotted against stick deflection in figure 6 indicate the revised aileron settings.

The spin and tumbling characteristics of the model were investigated with the propeller off and with the simulated propeller (fin area) installed. As has been indicated previously, the fin area was installed to simulate the windmilling propeller with power off for blade angles of 15° and 70°. No attempt was made to duplicate any power conditions.

The force tests were made at a dynamic pressure of 5 pounds per square foot and a corresponding Reynolds number of approximately 0.3×10^6 (based on the mean aerodynamic chord). The tunnel turbulence factor is 1.8. No tunnel wall or blocking corrections have been applied to the force data because of the small size of the model relative to the diameter of the tunnel. The angle-of-attack range for which the force tests were performed was 0° to 90°.

RESULTS AND DISCUSSION

Static Force Tests

The results of the static force tests are presented in figure 7. For the tests, all controls were set at neutral; the tests were conducted with the propeller off and with fin area installed on the model to represent the propeller at blade angles of 15° and 70°. The results show that the model would not trim at any unusual angles of attack even with fin area installed to simulate a 70° blade angle.

As has been stated previously, the area of the fins used to simulate the windmilling propeller was calculated by the method given in reference 1. Pitching-force tests conducted in another NACA facility on an XFY-1 model with propeller windmilling, results not presented, indicated that the computed fin area closely simulated the windmilling propeller at spinning attitudes. Thus it would be expected that the fin area added to the nose of the model should adequately simulate the windmilling propeller for the free-spinning and tumbling tests.

Erect-Spin Tests

The results of the model spin tests are presented in charts 1 to 6 and in table III. The model data are presented in terms of full-scale values for the airplane at an altitude of 20,000 feet. Inasmuch as similar results were obtained when the model was launched with spinning rotation either to pilot's right or left, all spinning results are arbitrarily presented for rotation to the pilot's right. No attempt was made to simulate power conditions, and the discussion that follows applies only for the propeller-windmilling case.

Full gross-weight loading.- The erect-spin and recovery data obtained for the full gross-weight loading (loading 1 in table II and fig. 5) with propeller off and with a simulated propeller at a 70° blade angle installed are presented in charts 1 and 2. The results with simulated propeller off and on were generally similar. For the normal spin control configuration (rudder full with the spin, elevator full up, and ailerons neutral) the model spins were rather flat and steady, and recoveries were rapid by rudder reversal. In general the model spun flat for all control configurations except for neutral and down settings of the elevators when the ailerons were set with the spin. Setting ailerons with the spin was indicated to have a favorable effect on recoveries whereas ailerons set against the spin was adverse. Recoveries were generally satisfactory for all spins by rudder reversal alone with the exception of the aileron-against spins for neutral and down settings of the elevator.

Mass variations.- Tests were conducted with the model ballasted to simulate the airplane condition with the mass most heavily distributed along the fuselage relative to the mass along the wings (loading 3 in table II and fig. 5) and the results for this loading are presented in charts 3 and 4. Comparison of these results with those presented in chart 1 shows that increasing the relative mass distribution along the fuselage had an adverse effect on the spin-recovery characteristics of the model, recoveries by rudder reversal being generally unsatisfactory except when the ailerons were with the spin. The spins generally were more oscillatory and had a slightly faster rate of rotation than for the full gross-weight loading (loading 1 in table II and fig. 5). The largest propeller blade angle simulated for these tests was 15°. Based on the results obtained for the full gross-weight loading, however, it appears unlikely that increasing the blade angle beyond this value would have any appreciable effect on recoveries.

Although unsatisfactory recoveries were generally obtained when the ailerons were at neutral or against the spin, the results indicate that when the ailerons were as much as one-half with the spin, fully reversing the rudder would terminate the spins rapidly. Satisfactory recoveries were also obtained from the criterion spin by simultaneous movement of ailerons to two-thirds with the spin and reversal of the rudder to two-thirds against the spin. On the basis of these results it is felt that satisfactory recoveries should be obtainable on the full-size airplane by movement of the rudder to full against the spin accompanied by simultaneous movement of the ailerons to with the spin (stick right in a right spin). Inasmuch as the largest aileron throw is available for elevator settings between approximately 2/3 up and 2/3 down (fig. 6) and inasmuch as a large aileron deflection to with the spin should result in optimum recoveries on the full-size airplane, the following recovery technique is recommended for this particular design: Fully reverse the rudder and simultaneously move the stick laterally to full with the spin and longitudinally to neutral. Such a control manipulation may possibly result in an aileron roll but this should be quickly terminated by neutralization of the ailerons. Ordinarily it is recommended that the rudder movement precede elevator reversal to prevent the elevators from shielding the rudder. Elevator shielding is not important on this particular design, however, because the top rudder is always shielded and the lower rudder is unshielded during spins, regardless of elevator position.

None of the other loading conditions indicated as possible on the airplane as tabulated in table II were tested because of their similarity to the loading conditions investigated. For loading conditions 3 and 4 tabulated in table II, it would be expected that results similar to those noted above would be obtained.

Other design variations.- Representatives of the Consolidated Vultee Aircraft Corporation had requested that the effects of removing the lower vertical tail, fixing the rudders at neutral, and removing the gun pods on the model's spin and recovery characteristics be determined. Results of tests conducted with the lower fin and rudder removed are presented in charts 5 and 6. Comparison of results presented in these charts with those presented in charts 1 and 3 indicates that the primary effect of removing the lower vertical tail on the steady-spin characteristics was an increase in the rate of rotation when the ailerons were against the spin. Removal of the lower fin and rudder had a decidedly adverse effect on recoveries, however, and, with the exception of the aileron-full-with spins, rudder reversal was ineffective in terminating the spins that were obtained. Unsatisfactory recoveries were obtained from the criterion spin even though movement of the rudder to against the spin was accompanied by aileron movement to its maximum deflection with the spin. On the basis of these results it would, therefore, be expected that unsatisfactory spin recoveries should be obtained on an XFY-1 airplane configuration having the lower fin and rudder removed.

On the basis of the results of brief tests (not presented in chart form) it appears that if the rudders are fixed at neutral the model would probably spin only for neutral or down settings of the elevator in combination with aileron settings against the spin. It would thus appear that aileron movement to full with the spin should terminate the spins obtained with the rudders fixed at neutral.

Results of brief tests (not presented on charts) indicated that the aerodynamic effect of the gun pods on the model's spin or spin-recovery characteristics was negligible. The weight of the gun pods is not known. Inasmuch as removal of the gun pods will result in an increase in the relative mass distribution along the fuselage, however, and inasmuch as aileron movement to with the spin becomes more effective in terminating spins as the relative mass distribution is increased along the fuselage, the previously recommended spin-recovery technique (rudder movement to full against the spin and aileron movement to full with the spin) should be effective in terminating spins of the airplane with gun pods removed.

Inverted Spins

Inasmuch as the XFY-1 airplane is a design which incorporates a vertical tail surface below the fuselage as well as above, the area of the lower fin and rudder being about the same as the upper fin and rudder, inverted-spin tests were not conducted since it was felt that the inverted spin and recovery characteristics would be essentially the same as the erect spin and recovery characteristics. Thus, for any loading condition indicated possible on the airplane in table II, any inverted spins obtained should be satisfactorily terminated by fully reversing the rudder and then immediately moving the stick laterally towards the forward rudder pedal, the stick being moved longitudinally toward neutral. This control movement corresponds to moving the ailerons with the inverted spin while the rudder is moved to oppose the spin rotation.

Spin-Recovery Parachutes

The results of the spin-recovery parachute tests are presented in table III. Most of these tests were conducted for the control configuration with elevator neutral and ailerons one-half against the spin, a configuration from which rudder reversal gave slow recoveries. A few tests were also conducted at the criterion-spin-control setting. Several sizes of tail parachutes were investigated with different towline lengths and it was noted that either the parachutes tended to deflate and occasionaly foul on the vertical tail or the time required for the canopy to inflate after the parachute pack was released was quite long, sometimes requiring as much as one turn. This behavior of the parachute is attributed to the fact that the parachute was blanketed by the wing at times. The tendency for the parachute to deflate decreased as the parachute size and towline length increased and the tendency for the parachute to foul on the vertical tail was observed only when the packed parachute was ejected from the outboard side of the model (left side in a right spin). Based on the results presented in table III, it appears that a 21.7-foot-diameter (laid out flat) parachute with a towline length of 25 feet (all values full-scale) ejected from the inboard side of the vertical tail may terminate the spins of the airplane provided the parachute canopy inflates satisfactorily after it is ejected. Because of the difficulties encountered in the model tests, however, it would appear that a wing-tip parachute might be more reliable as an emergency spin-recovery device. The results of the wing-tip parachute tests showed that a 13.3-foot flat-type parachute attached to a 25-foot towline should satisfactorily terminate demonstration spins on the full-scale airplane. Using a shorter towline occasionally resulted in the parachute deflating and fouling on the fin. The drag coefficient of the tail and wing-tip parachutes investigated was approximately 0.7. The parachutes used in this investigation were flat-type parachutes which are unstable. If the full-scale parachute installation is to be tested in level flight before spins are attempted, low-porosity flat-type parachutes may cause violent pitching and yawing gyrations. Use of a stable-type parachute, described in reference 4, will eliminate this possibility and may be more desirable than a conventional-type parachute.

Control Forces

The discussion of the results so far has been based on control effectiveness alone without regard to the forces required to reverse the controls. As previously mentioned, for all tests, sufficient force was applied to the controls to move them fully and rapidly. Sufficient force must be applied to the airplane controls to move them in a similar manner in order for the model and airplane results to be comparable.

Results of tests indicated that the force required to reverse the rudder would be rather high, approximately 300 pounds, but within the capabilities of a pilot (ref. 5). Because of lack of detail in the rudder balance of the model, of inertia mass-balance effects, and of scale effect, these results are only a qualitative indication of the actual forces that may be experienced. No tests were conducted to determine the stick force required to move the ailerons to full with the spin. To assure satisfactory recoveries from spins of this airplane, however, provision should be made to permit full movement of the ailerons.

Recommended Spin-Recovery Technique

Based on the results obtained with the model, the following recommendations are made as to recovery technique for all loadings and conditions of the airplane with the propeller windmilling:

For erect spins, the rudder should be reversed briskly from full with the spin to full against the spin accompanied by simultaneous lateral movement of the stick to full with the spin (stick full right in a right spin) and longitudinal movement of the stick to neutral. After the spin rotation has ceased, the airplane may go into a vertical aileron roll which can be quickly terminated by neutralizing the stick laterally.

For recovery from inverted spins the rudder should be fully reversed to oppose the spin rotation and immediately thereafter the stick should be moved fully laterally towards the forward rudder pedal and longitudinally to neutral. (With rudder opposing the spin rotation the stick should be moved laterally so that the controls are together; i.e., if the right rudder pedal is moved forward to move the rudder to oppose the spin rotation, the stick should be moved laterally to the right.)

Tumbling Tests

Tumbling tests were conducted with the model in the full gross-weight loading (center of gravity at 16.3 percent $\bar{c}$) with the ailerons and rudder at neutral. The results of these tests (not presented in tabular form) showed that the model had no tendency to tumble at any elevator setting with the propeller off or with fins simulating a 70° propeller blade angle installed.

When launched with forced pitching rotation the tumbling imparted to the model was damped out after about 1 or 2 turns and a pitching oscillation encountered by the model after the tumbling had ceased was damped out rapidly. When launched from a whip-stall attitude, the model pitched its nose downward and oscillated in pitch for a short period before diving out. Although these tests were conducted only for the full gross-weight loading (loading 1 in table II), based on the tumbling criterion presented in reference 6, it would be expected that the XFY-1 should resist tumbling for any of the loading conditions tabulated in table II.

CONCLUSIONS

Based on the results of tests of a 1/20-scale model of the Consolidated Vultee XFY-1 airplane with a windmilling propeller simulated to determine the effects of control setting and movements upon the erect spin and recovery characteristics for a range of airplane-loading conditions, the following conclusions regarding the spin, spin-recovery, tumbling, and longitudinal-trim characteristics of the airplane are made:

1. The airplane will spin at a flat attitude and the spins will be fairly steady. The spin-recovery characteristics of the airplane will be satisfactory for all loadings if the following technique is used: Brisk rudder reversal accompanied by simultaneous movement of the ailerons to full with the spin (stick right in a right spin) and longitudinal movement of the stick to neutral. After the spin rotation has ceased, the stick should be neutralized laterally to check any aileron roll which may develop.

2. Increasing the pitch angle of the windmilling propeller blades will have little effect on the spin-recovery characteristics.

3. A 13.3-foot flat-type parachute (drag coefficient approximately 0.7) attached to the outer wing tip with a 25-foot towline will effect satisfactory emergency recoveries from demonstration spins. A flat-type tail parachute 21.7 feet in diameter (drag coefficient approximately 0.7) with a 25-foot towline will adequately damp the spin rotation but may not be as reliable in operation as the wing-tip parachute.

4. For satisfactory recovery from inverted spins, rudder reversal to against the spin should be followed immediately by movement of the stick laterally towards the forward rudder pedal and longitudinal movement of the stick to neutral (i.e., if right rudder pedal is moved forward to oppose spin rotation, the stick should be moved laterally to the right).

5. The airplane will not tumble for any of the loading conditions indicated possible.

6. The airplane will have no unusual longitudinal-trim characteristics.

7. Removal of the gun pods or fixing the rudders at neutral will not adversely affect the airplane's spin-recovery characteristics. Removal of the lower vertical tail, however, will result in unsatisfactory spin-recovery characteristics.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE CONSOLIDATED VULTEE XFY-1 MODEL AS SIMULATED ON THE 1/20-SCALE SPIN MODEL

Length, over-all, ft	32.18
Tail-damping power factor	2514×10^{-6}
Wing:	
Span, (not including pods), ft	25.67
Area, sq ft	346
Airfoil section	NACA 63-009
Mean aerodynamic chord, in.	186.9
Leading edge $\bar{c}$ behind wing apex, in.	85.20
Tip chord, in.	52.00
Root, chord, in.	272.00
Incidence, deg	0
Dihedral, deg	0
Taper ratio	5.23
Effective aspect ratio	1.9
Distance from normal center of gravity to intersection of elevon hinge line and fuselage center line, in.	134.6
Distance from normal center of gravity to intersection of rudder hinge line and fuselage center line, in.	135.0
Sweepback of leading edge of wing, deg	55.0
Sweepback of trailing edge of wing, deg	0.0
Elevon:	
Span, ft	10.02
Chord behind hinge line (constant), in.	21.80
Area of elevon rearward of hinge line (total), sq ft	36.2
Vertical tail:	
Span, over-all, ft	22.97
Total area, sq ft	160.5
Rudder area rearward of hinge line, sq ft	20.75
Sweepback of leading edge of fin, deg	40.0
Sweepback of trailing edge of fin, deg	3.0

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE CONSOLIDATED VULTEE XFY-1 AIRPLANE AND FOR THE LOADINGS TESTED ON THE 1/20-SCALE MODEL

[Model values are given as corresponding full-scale values; moments of inertia are given about the center of gravity]

Loading	Loading condition	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft^2			Mass parameters		
			$x/\bar{c}$	$z/\bar{c}$	Sea level	20,000 ft	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane values												
1	Full-load gross weight	16,250	0.163	0.0212	23.90	44.84	12,016	23,361	30,647	-341×10^{-4}	-219×10^{-4}	560×10^{-4}
2	Gun pods installed, 55 percent fuel	15,153	.136		22.30	41.90	10,365	26,126	32,909	-508	-219	727
3	Rocket pods installed, 55 percent fuel	14,376	.104		21.14	39.67	7,830	23,802	28,081	-543	-145	688
4	Gun pods installed, 42 percent fuel	14,565	.136		21.40	40.17	10,257	25,334	32,933	-506	-255	761
Model values												
1	Full-load gross weight	16,199	.163	.0212	23.82	44.70	12,250	24,047	32,717	-356	-262	618
3	Rocket pods installed, 55 percent fuel	14,534	.110	.0215	21.36	40.08	7,266	23,727	27,965	-554	-143	697

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TABLE III.- SPIN-RECOVERY PARACHUTE DATA OBTAINED WITH A 1/20-SCALE

MODEL OF THE CONSOLIDATED VULTEE XFY-1 AIRPLANE

[Full gross-weight loading (loading 1 in table II and fig. 5); rudder fixed full with the spin and recovery attempted by opening the parachute only; model values converted to corresponding full-scale values; C_D of parachutes approximately 0.7; right erect spins]

Parachute diameter, ft	Towline length, ft	Ailerons	Elevator	Turns for recovery
		[a]Tail parachutes		
10.8	13.4	10° against	Neutral	∞
11.7	25.0	7° against	20° up	>13, 14
16.7	13.4	7° against	20° up	3, 4, $4\frac{1}{2}$, $5\frac{1}{2}$
16.7	13.4	10° against	Neutral	6, 7
16.7	25.0	10° against	Neutral	4
16.7	25.0	7° against	20° up	$3\frac{1}{2}$, 4
18.3	13.4	7° against	20° up	3, $4\frac{1}{2}$, $5\frac{1}{2}$
20.0	5.0	10° against	Neutral	8
20.0	25.0	10° against	Neutral	3, 3
20.0	25.0	7° against	20° up	$1\frac{1}{2}$, $1\frac{3}{4}$, $2\frac{1}{2}$, 3, 3
21.7	25.0	7° against	20° up	$1\frac{1}{2}$, 2, 2
		Wing-tip parachutes		
10.8	13.8	10° against	Neutral	3, 3, $3\frac{1}{4}$, [b]∞
12.5	25.0	10° against	Neutral	$1\frac{1}{2}$, $1\frac{3}{4}$, 2, [b]∞
13.4	6.7	10° against	Neutral	[b]∞
13.4	13.8	10° against	Neutral	$1\frac{1}{2}$, $1\frac{3}{4}$, 2, [b]∞
13.3	25.0	10° against	Neutral	$1\frac{1}{2}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 1, 1, $1\frac{1}{4}$, 1
15.0	25.0	10° against	Neutral	$1\frac{1}{4}$, 1, 1, 2
16.7	25.0	10° against	Neutral	$1\frac{3}{4}$, 2
		Fin-tip parachute		
13.3	25.0	10° against	Neutral	∞, [b]∞

[a]Tail parachutes generally tended to deflate when ejected from either side of the fin, and when ejected from the outboard side of the fin the tail parachutes occasionally fouled on the fin. Recovery data presented for those instances when the parachute did not foul.

[b]Parachute deflated and fouled on the fin.

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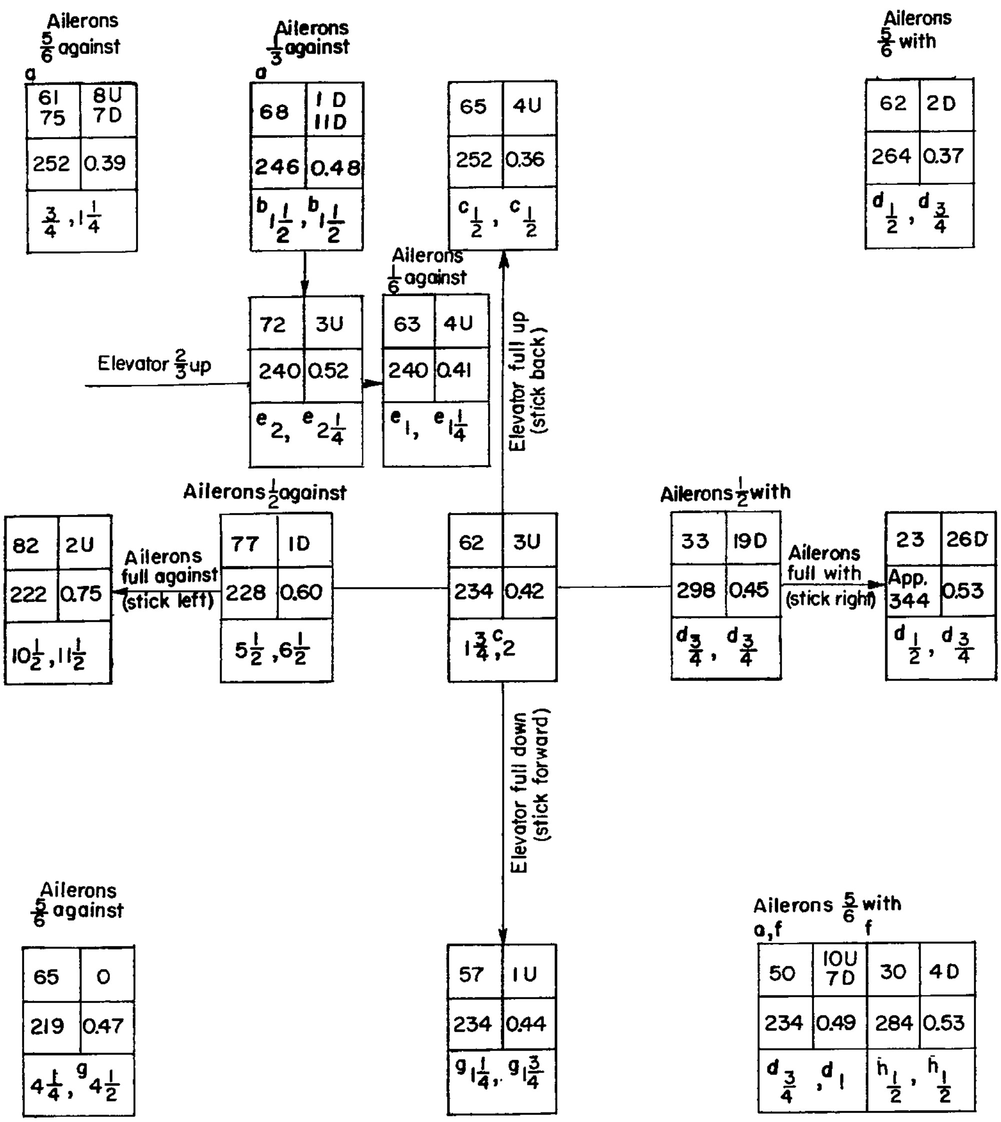
CHART 1.-SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL FOR LOADING I WITH PROPELLER OFF

[Loading 1 in table II and figure 5 $\left(\frac{I_X - I_Y}{mb^2} = -350 \times 10^{-4}\right)$; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder full with spins); right erect spins]



[a] Oscillatory spin. Range or average values given.

[b] Recovery attempted by reversing rudders from full with to $\frac{2}{3}$ against and ailerons from $\frac{1}{3}$ against to $\frac{2}{3}$ with the spin.

[c] Model goes inverted momentarily then dives on recovery.

[d] Recovers in a vertical aileron roll.

[e] Recovery attempted by reversing rudders from full with to $\frac{2}{3}$ against the spin.

[f] Two conditions possible.

[g] Model goes inverted on recovery.

[h] Recovers in an inverted spin to pilot's right.

Model values converted to corresponding full-scale values
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

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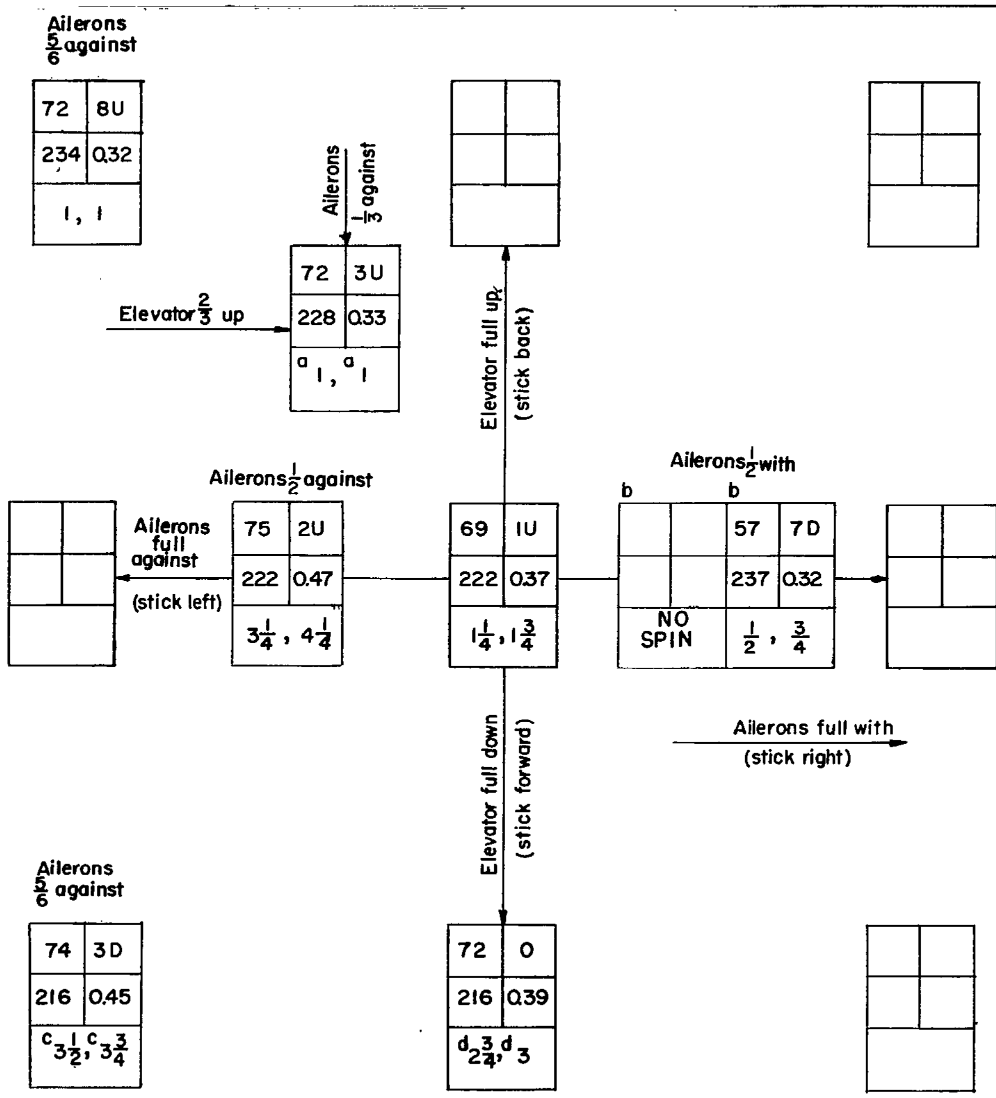
CHART 2.-SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL FOR LOADING I WITH 70° PROPELLER BLADE ANGLE SIMULATED

[Loading I in table II and figure 5 $\left(\frac{I_X - I_Y}{mb^2} = -350 \times 10^{-4}\right)$; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder full with spins); right erect spins]



[a] Recovery attempted by reversing rudders from full with to $\frac{2}{3}$ against the spin.
[b] Two conditions possible.
[c] Model goes inverted on recovery.
[d] Model dives and rolls or goes inverted on recovery.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

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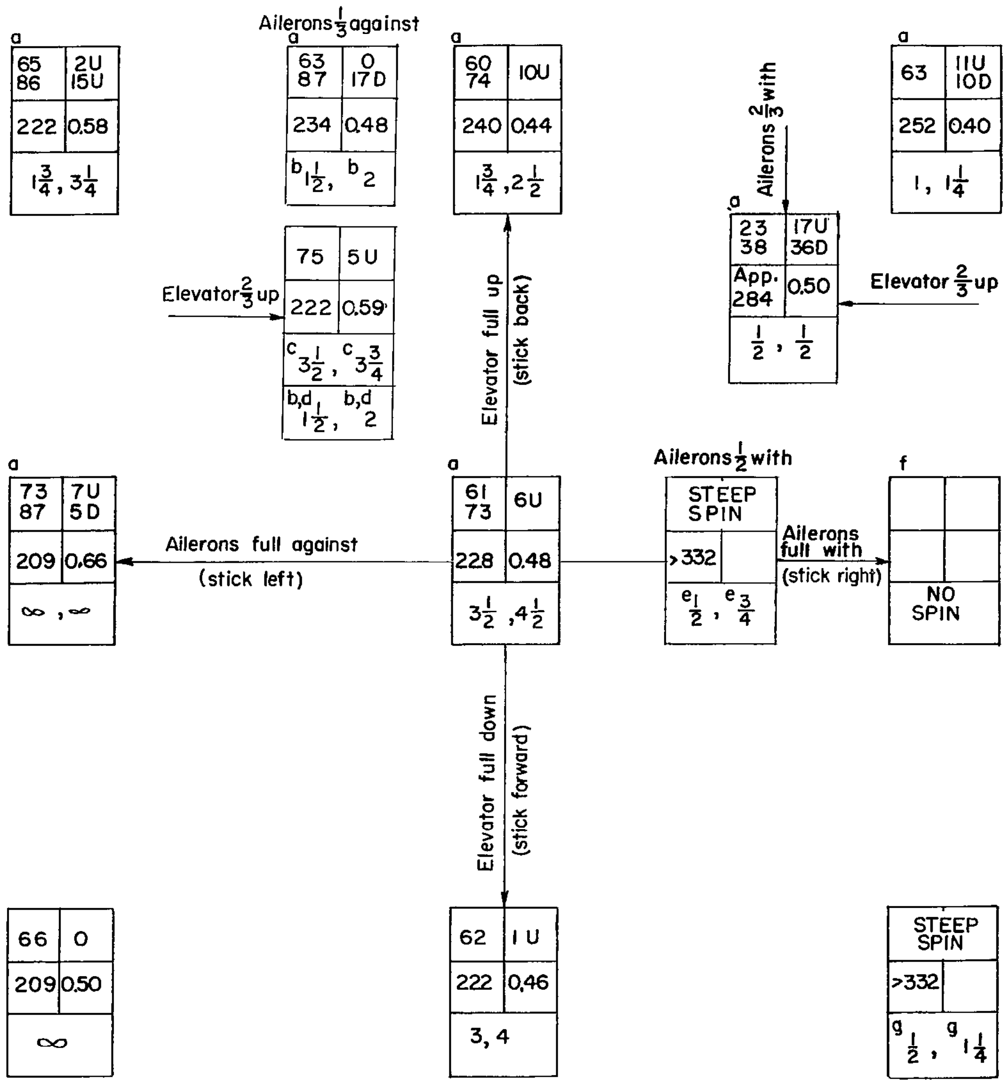
CHART 3.–SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL FOR LOADING 3 WITH PROPELLER OFF

[Loading 3 in table II and figure 5 $\left(\frac{I_X - I_Y}{mb^2} = -550 \times 10^{-4}\right)$, recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder full with spins), right erect spins]



[a] Oscillatory spin. Average value or range of values given.

[b] Recovery attempted by reversing rudders from full with to ⅔ against the spin and ailerons from ⅓ against to ⅔ with the spin.

[c] Recovery attempted by reversing the rudders from full with to ⅔ against the spin.

[d] Visual estimate.

[e] Recovers in a vertical aileron roll.

[f] After launching rotation expended model goes into a vertical aileron roll.

[g] Recovers in an inverted spin to pilot's right.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

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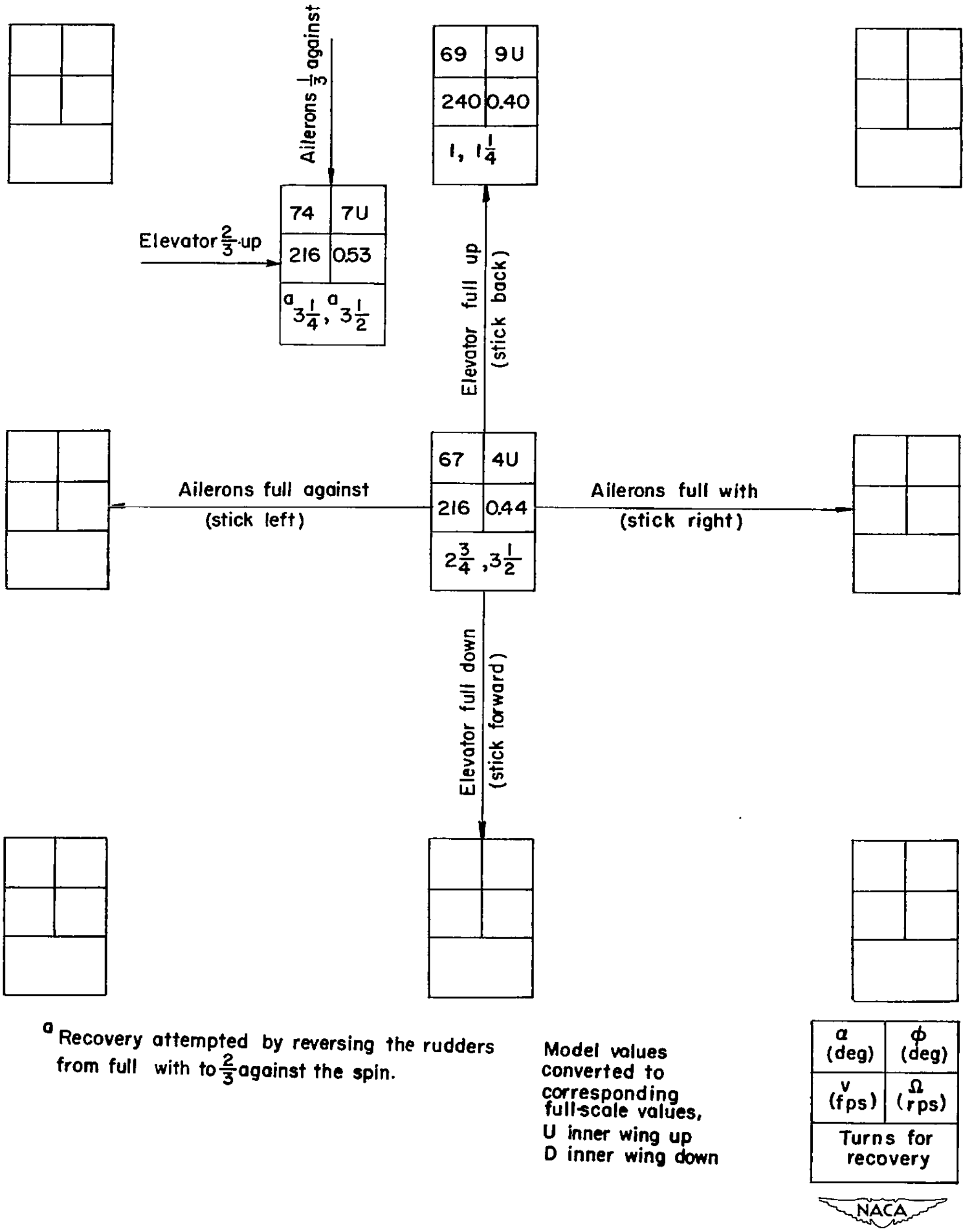
CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL FOR LOADING 3 WITH 15° PROPELLER BLADE ANGLE SIMULATED

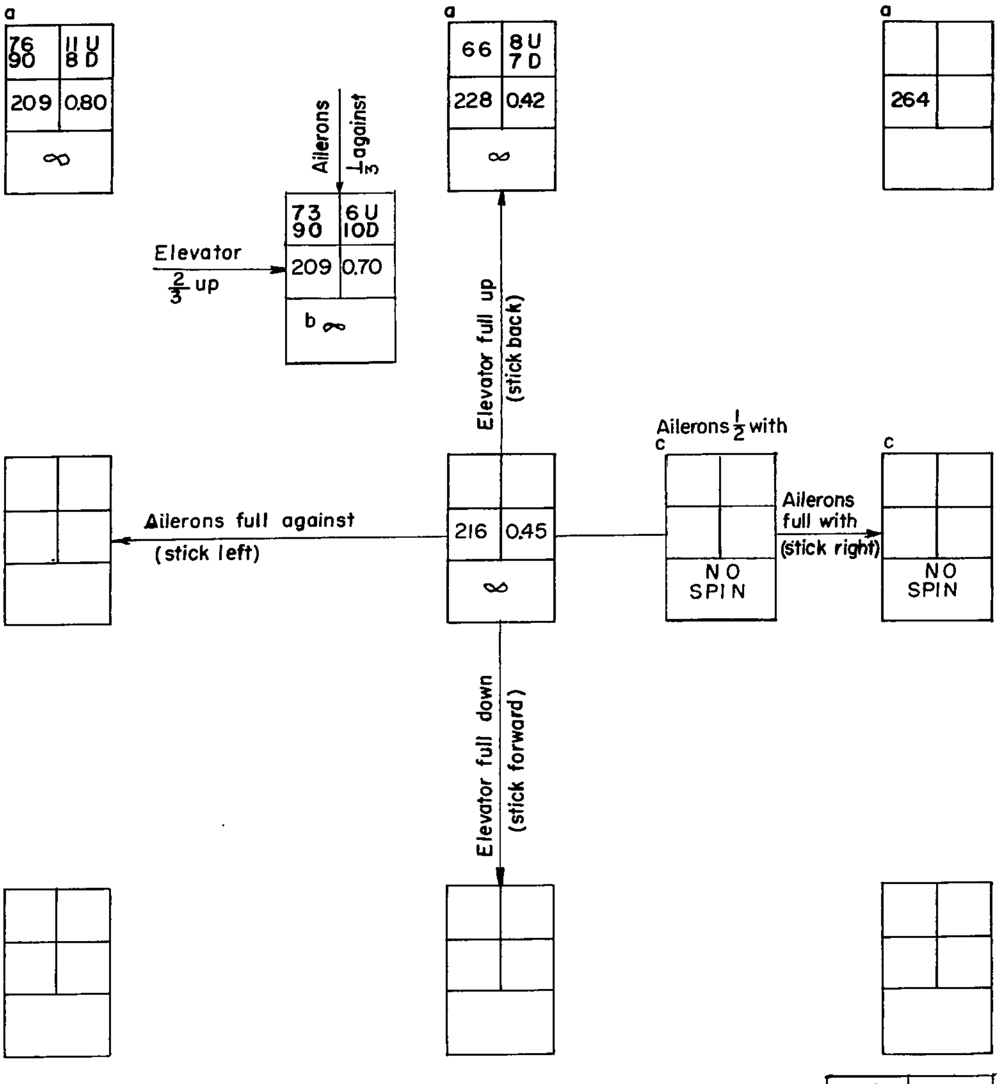
[Loading 3 in table II and figure 5 $\left(\frac{I_X - I_Y}{mb^2} = -550 \times 10^{-4}\right)$; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder full with spins); right erect spins]



[a] Recovery attempted by reversing the rudders from full with to 2/3 against the spin.

CHART 5.-SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL FOR LOADING 3 WITH LOWER VERTICAL TAIL REMOVED

[Loading 3 in table II and figure 5 $\left(\frac{I_X - I_Y}{mb^2} = -550 \times 10^{-4}\right)$; recovery attempted by rapid full rudder reversal except as noted(recovery attemptd from,and steady-spin data presented for, rudder full with spins); right erect spins; propellers off]



[a]Oscillatory spin. Range or average values given.
[b]Recovery attempted by reversing rudder from full with to $\frac{2}{3}$ against the spin.
[c]After launching rotation expended model goes into a vertical aileron roll.

Model values converted to corresponding full-scale values
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

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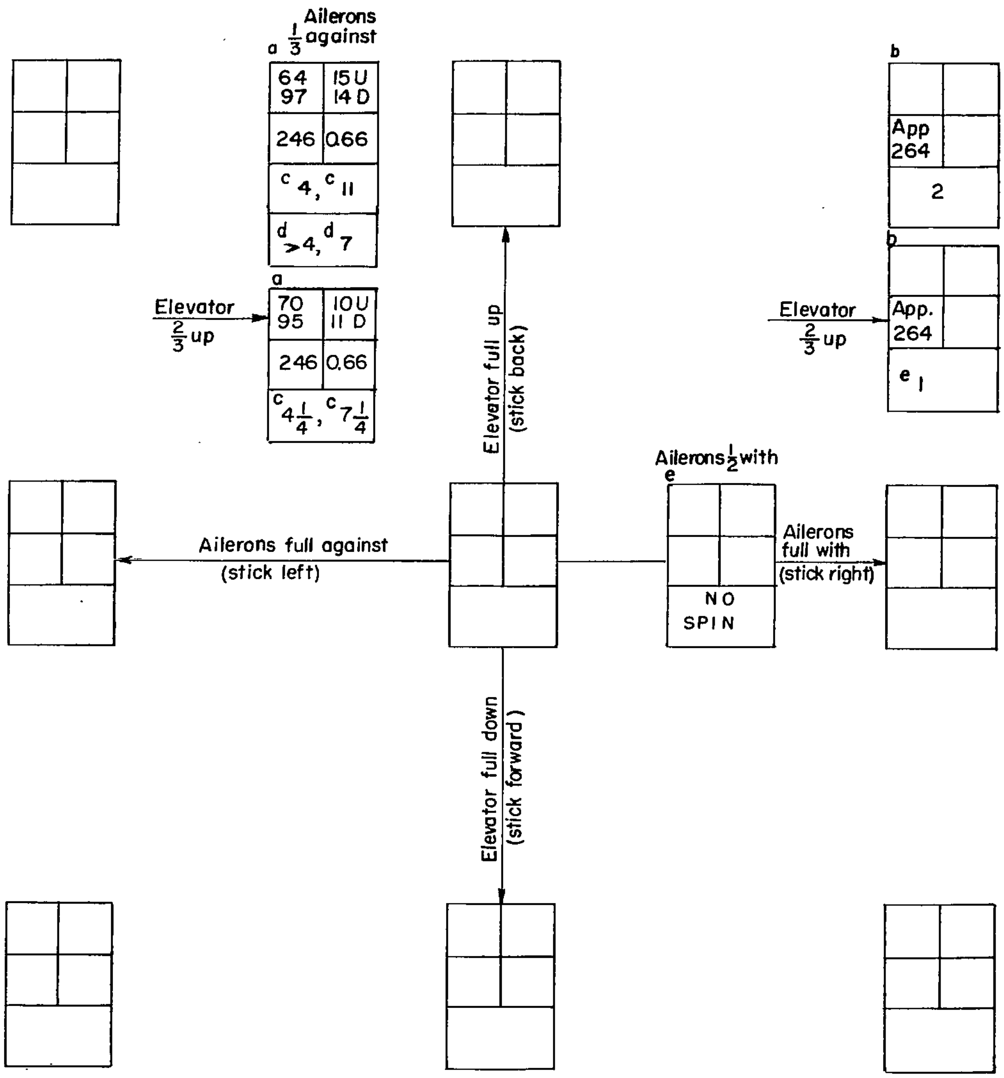
CHART 6.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL FOR LOADING I WITH LOWER VERTICAL TAIL REMOVED

[Loading I in table II and figure 5 $\left(\frac{I_X - I_Y}{mb^2} = -350 \times 10^{-4}\right)$; recovery attempted by rapid full rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder full with spins); right erect spins; propellers off]



[a] Oscillatory spin. Range or average values given.
[b] Wandering and whipping spin.
[c] Recovery attempted by simultaneously reversing rudder to 2/3 against and moving ailerons to full with the spin.
[d] Recovery attempted by simultaneously reversing rudder to 2/3 against, moving the ailerons to 2/3 with the spin and moving elevators to neutral.
[e] Goes into a steep aileron roll.

Model values converted to corresponding full-scale values

U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

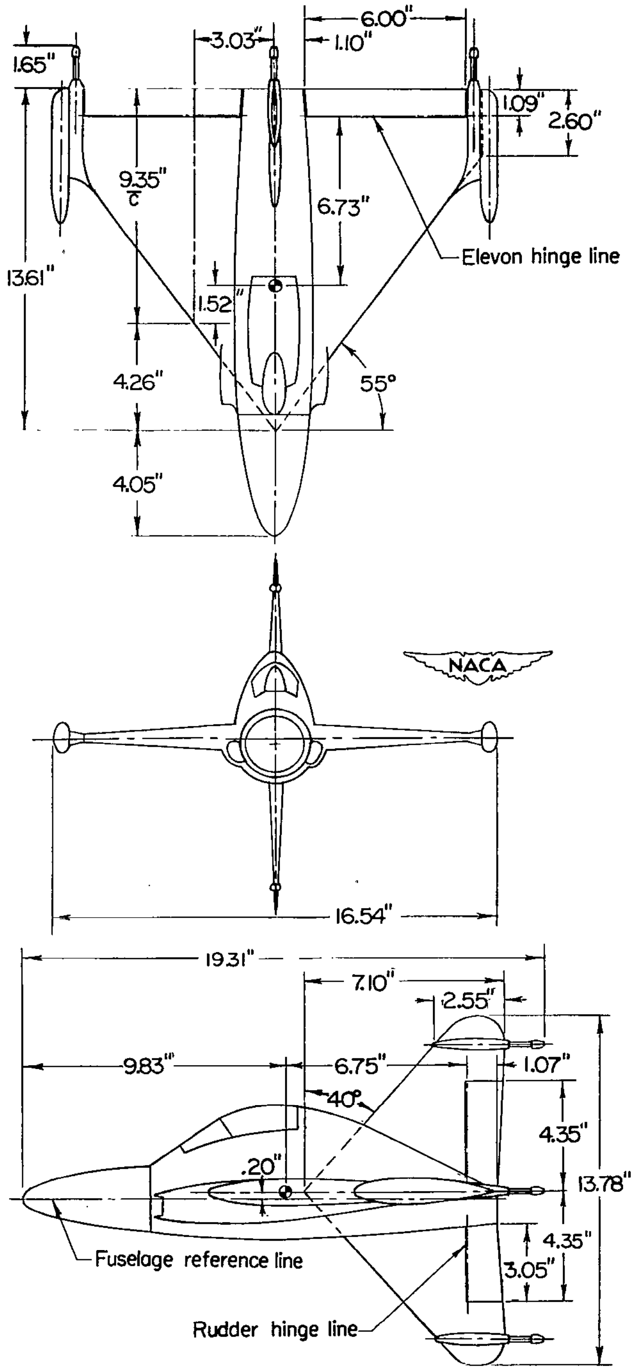


Figure 1.- Three-view drawing of the 1/20-scale model of the Consolidated Vultee XFY-1 airplane as tested in Langley 20-foot free-spinning tunnel. Dimensions are model values. Center-of-gravity position shown is for the full gross-weight loading.

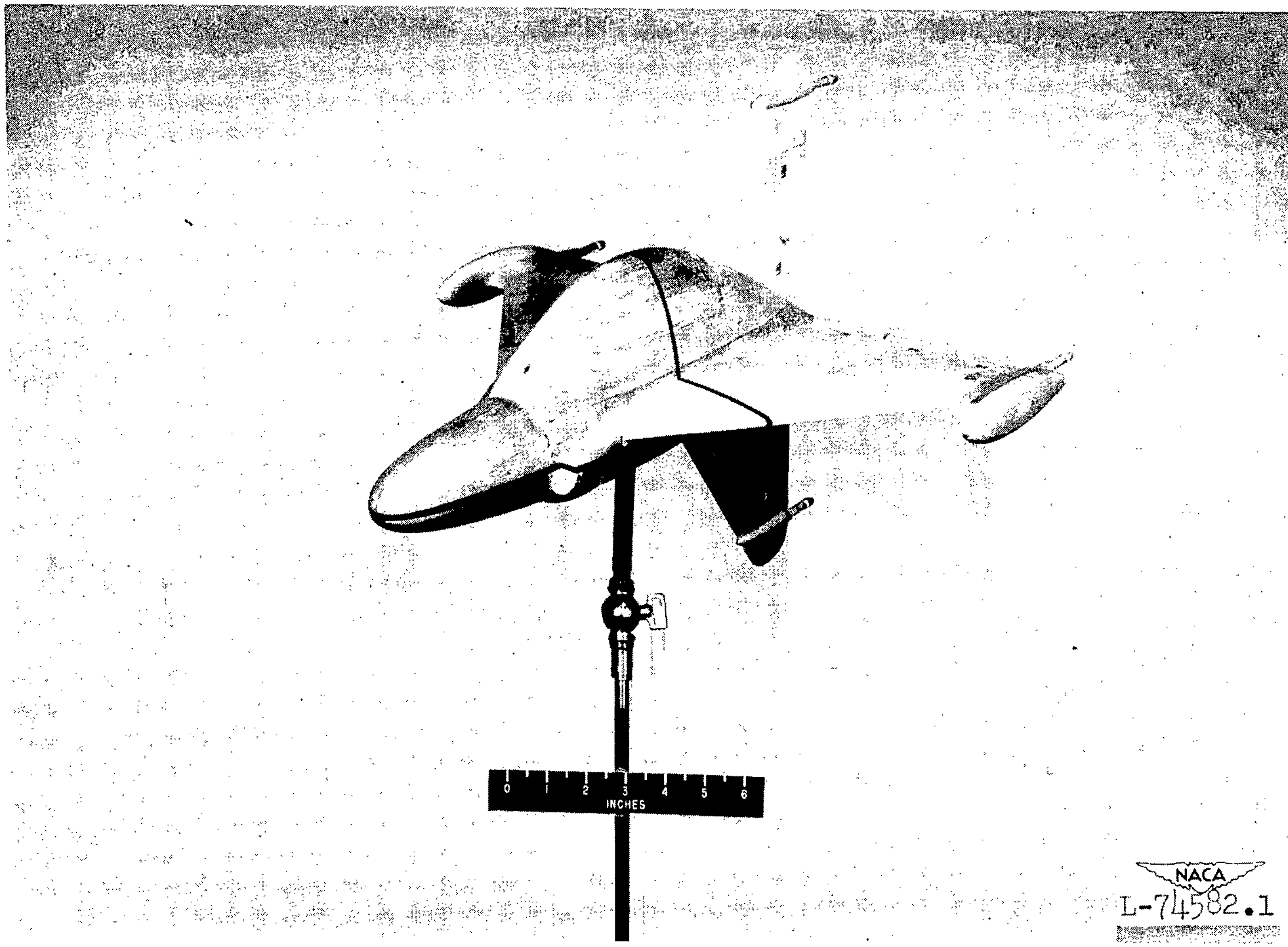


Figure 2.- Photograph of the model of the Consolidated Vultee XFY-1 airplane as tested in the Langley 20-foot free-spinning tunnel.

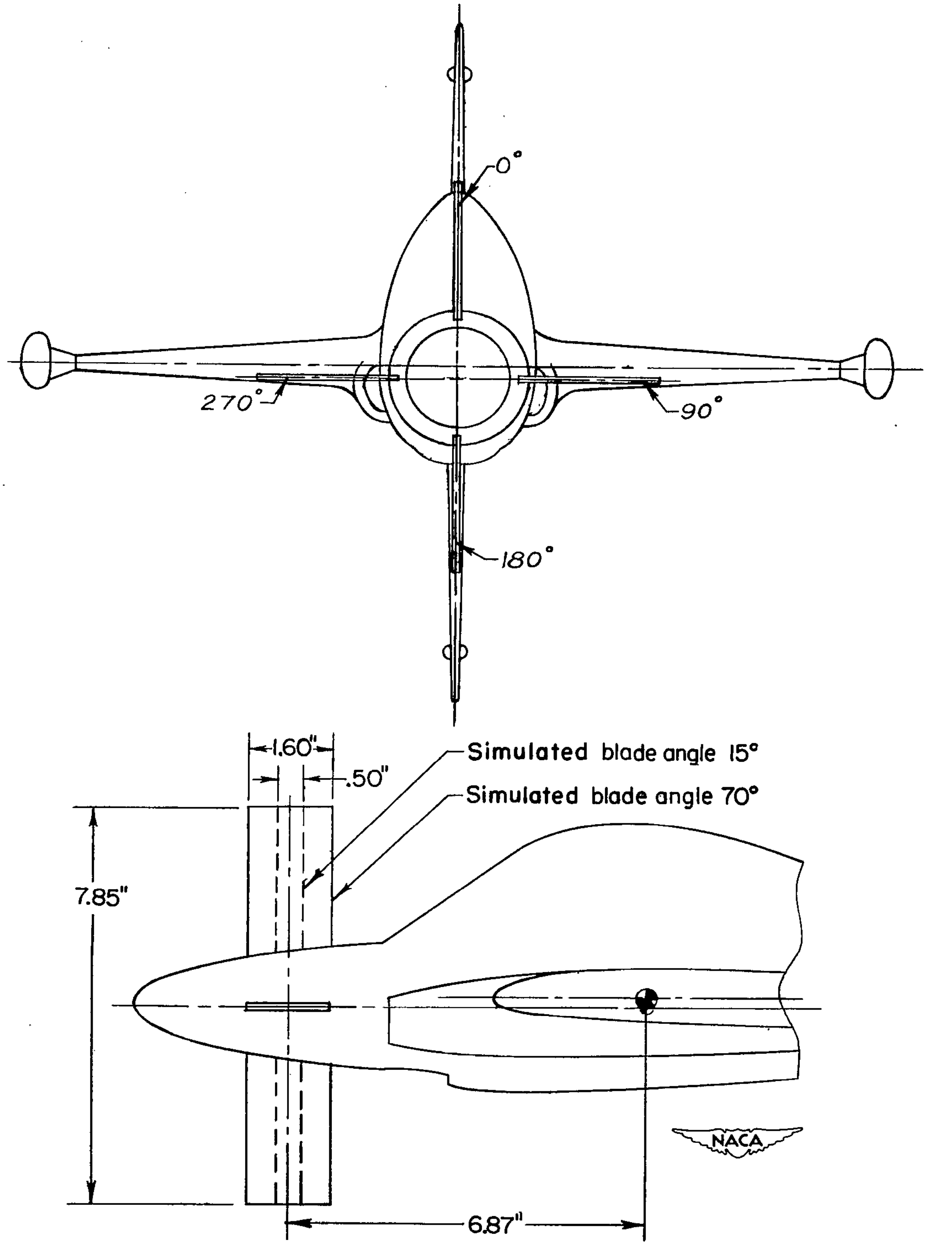


Figure 3.- Drawing of the fin area simulating the propeller as tested on the 1/20-scale model of the Consolidated Vultee XFY-1 airplane. Center-of-gravity position shown is for the full gross-weight loading.

Figure 4.- Photograph of the model spinning in the Langley 20-foot free-spinning tunnel.

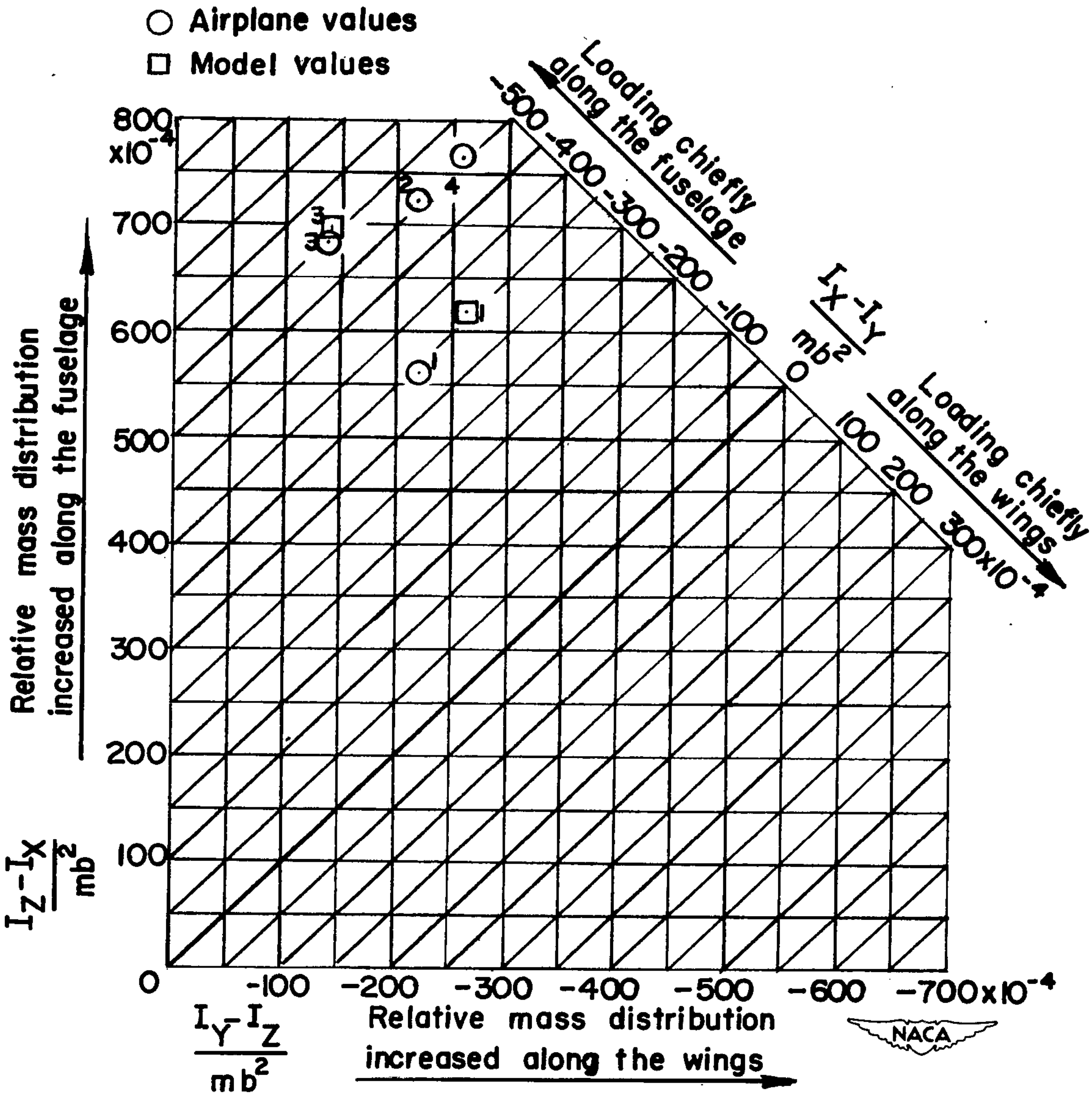


Figure 5.- Mass parameters for loadings possible on the Consolidated Vultee XFY-1 airplane and for the loadings tested on the 1/20-scale model. (Points correspond to numbered loadings in table II.)

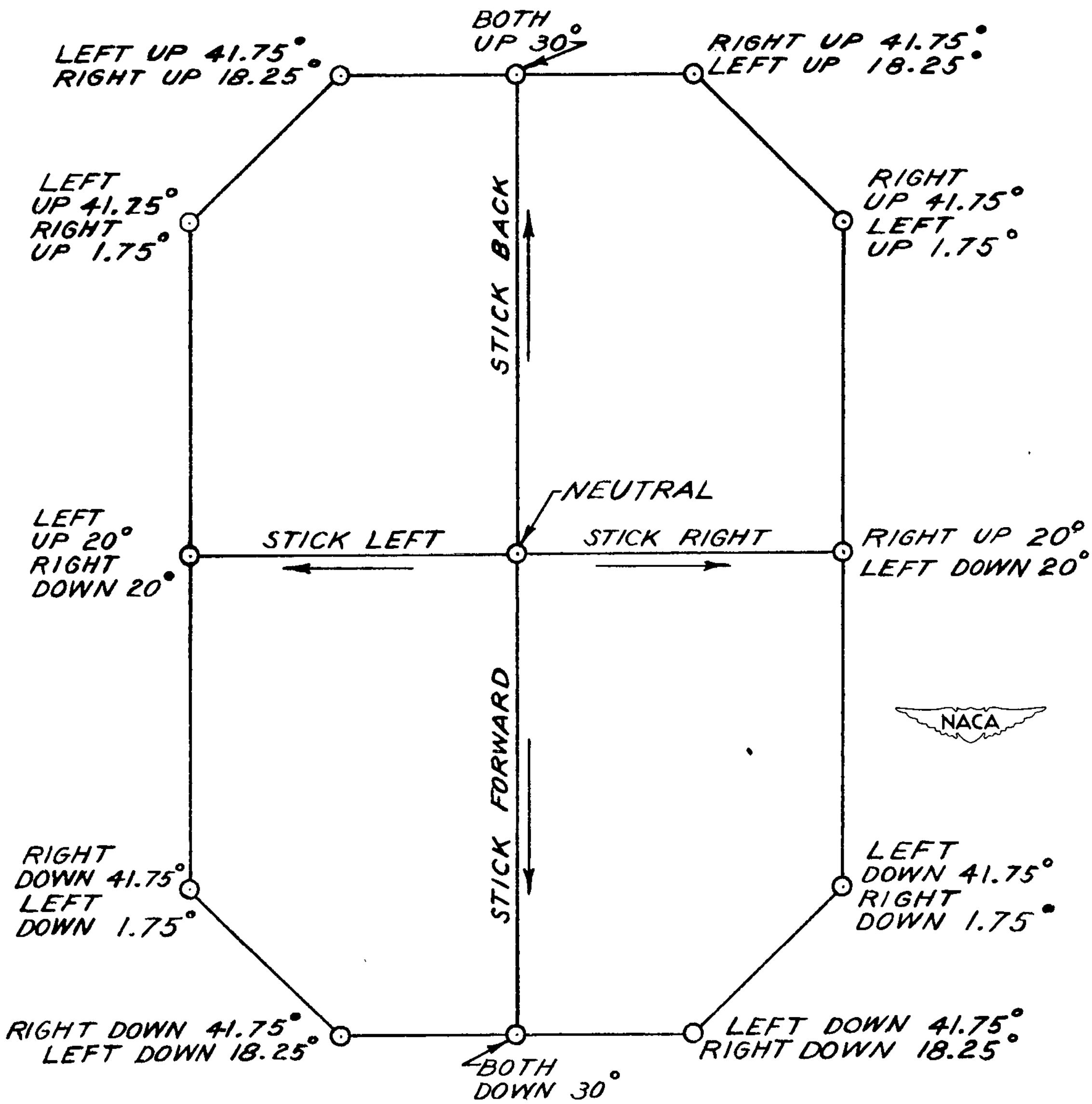


Figure 6.- Deflection of elevon surfaces relative to control-stick motion. Envelope of stick and elevon movement shown. Elevon position is directly proportional to control stick position; angles are measured in plane normal to hinge center line.

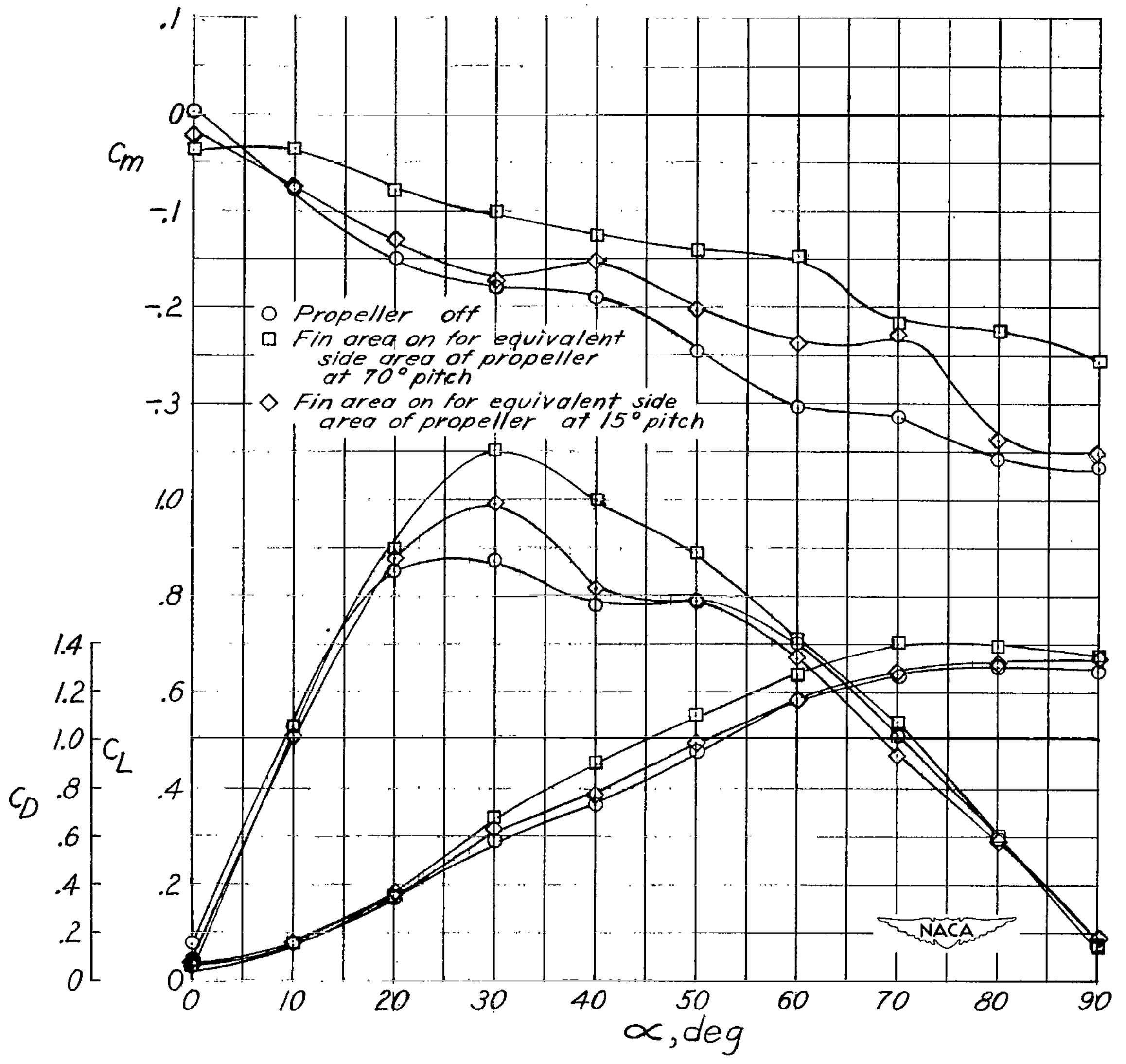


Figure 7.- Aerodynamic characteristics of the 1/20-scale model of the Consolidated Vultee XFY-1 airplane. Center of gravity located at 16.3 percent of the mean aerodynamic chord. All controls set at neutral. $\psi = 0^{\circ}$.